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COMPARISON OF NOISEMAP COMPUTER PROGRAM WITH AND WITHOUT THE SAE LATERAL ATTENUATION MODEL

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FOR THE COMMANDER

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This study compares the noise contours generated by using the lateral attenuation model presently incorporated in NOISEMAP and the new SAE attenuation model, described in the Aerospace Information Report AIR 1751 (March 1981). Because the SAE model assumes higher attenuation values than those now used in NOISEMAP, contours based upon the SAE model are smaller in area than those based upon NOISEMAP. In comparing next page

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the two attenuation models, the areas within SEL contours were calculated for both the F-4 and the B-52 airplanes. Additionally, the SEL contours using the two attenuation models were computed for the takeoff and landing operations associated with the F-4. Field measured data at a civilian airport in California were used in order to compare the effectiveness of the two attenuation models when applied to calculating single event and cumulative noise exposure contours. In general both models yielded predicted values that agreed well with field measured data for elevation angles of 25 degrees and higher. However, field measured data were simply not available at more critical lower elevation angles (zero to 25 degrees), and thus it was not possible to conclude at this time which attenuation model is better.

Additional studies are recommended in order to directly compare the predicted noise environments using these two different lateral attenuation models with field measured data at elevation angles of zero to 25 degrees.

SUMMARY

This study compares the noise contours generated by using the lateral attenuation model presently incorporated to NOISEMAP and the new SAE attenuation model described in the Aerospace Information Report AIR 1751 (March 1981). Because the SAE model assumes higher attenuation values than those now used in NOISEMAP, contours based upon the SAE model are smaller in area than those based upon NOISEMAP. In comparing the two attenuation models, the areas within SEL contours were calculated for both the F-4 and the B-52 airplanes. Additionally, the SEL contours using the two attenuation models were computed for the takeoff and landing operations associated with the F-4. Field measured data at a civilian airport in California were used in order to compare the effectiveness of the two attenuation models when applied to calculating single event and cumulative noise exposure contours. In general both models yielded predicted values that agreed well with field measured data for elevation angles of 25 degrees and higher. However, field measured data were simply not available at the more critical lower elevation angles (zero to 25 degrees), and thus it was not possible to conclude at this time which attenuation model is better.

Additional studies are recommended in order to directly compare the predicted noise environments using these two different lateral attenuation models with field measured data at elevation angles of zero to 25 degrees.

PREFACE

This research was performed for the Air Force Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base, Ohio, under Project/Task 723107, Technology to Define and Assess Environmental Quality of Noise From Air Force Operations. Technical monitor for this effort was Mr. Jerry D. Speakman of the Biodynamic Environment Branch, Biodynamics and Bioengineering Division.

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INTRODUCTION

The standard NOISEMAP computer program contains an algorithm for calculating the lateral attenuation of sound from an airplane during takeoff and landing operations (Ref. 1). Recently, the Society of Automotive Engineers (SAE) has adopted a new algorithm for predicting airplane sound propagation for these low angles of elevation (Ref. 2). This report describes the difference in results between the SAE lateral attenuation model and the current algorithm in NOISEMAP.

In an effort to evaluate the sensitivity of these alternate algorithms, two versions of NOISEMAP were used in this study:

1) the existing NOISEMAP computer program, and

2) the NOISEMAP computer program modified to incorporate the SAE lateral attenuation model.

The SEL data base in both versions of NOISEMAP assumed that the relative duration increases at the rate of 6 times the logarithm of the ratio of the slant distance.

In this report, the technical discussion differentiates between the two lateral attenuation methods and explains the concept of the relative signal duration adjustment. The results section focuses upon a comparison of the two lateral attenuation models when used to predict sound exposure level (SEL) contours for selected (F-4 and B-52) military airplanes. Also included in this section are the results of a similar comparison of the two lateral attenuation methods for both predicted and measured civil airport operations noise data. The last section contains the conclusions.

TECHNICAL DISCUSSION

NOISEMAP: LATERAL ATTENUATION MODEL

The lateral attenuation algorithm that is currently incorporated into the NOISEMAP computer program assumes the existence of two distinct noise level versus-distance curves. These two curves are descriptively named the air-to-ground and the ground-to-ground propagation curves. The lower noise levels of the ground-to-ground curve are attributable to excess ground attenuation and shielding effects of intervening structures.

When the aircraft is either on the ground or high in the air, it is evident which of the two curves is applicable. However, when the airplane is at low angles of elevation it is necessary to interpolate between the two propagation curves.

The interpolation or transition coefficient, T, is a function of the angle of elevation (β). This angle (β) is formed at the point where the ground plane meets the line of sight from the airplane at its closest point of approach to the observer.

The transition coefficient is then used to determine the sound exposure level (SEL) as follows:

$$L_{AE} = \left[(L_{AE}G\text{-}G)(T) + (L_{AE}A\text{-}G)(1-T)\right] \qquad (1)$$

where,

$L_{AE}G\text{-}G$ = ground-to-ground sound exposure level, versus distance curve,

$L_{AE}A\text{-}G$ = air-to-ground sound exposure level, versus distance curve.

$T = 1$ for $\beta \leq 4.3°$

$T = 2.5 - 0.3491\,\beta$ for $4.3° < \beta < 7.2°$

$T = 0$ for $\beta \geq 7.2°$

SAE AIR 1751: LATERAL ATTENUATION MODEL

The SAE algorithm also takes into consideration the transition zone between the long-range air-to-ground attenuation prediction curve and the overground attenuation prediction curve. The function which represents this transition region is the product of the functions which describe the air-to-ground and the overground attenuation curves divided by 13.86 (defined as the limit of G (ℓ) at long range). The following equation is used to calculate the lateral attenuation:

$$\Lambda(\beta,\ell) = \frac{G(\ell)\ \Lambda(\beta)}{13.86},\ \text{dB} \qquad (2)$$

where the air-to-ground attenuation factor is calculated as follows:

$$\Lambda(\beta) = 3.96 - 0.66\,\beta + 9.90e^{-0.13\beta},\ \text{dB},\ 0° \leq \beta \leq 60°,$$

and (2a)

$$\Lambda(\beta) = 0,\ \text{dB},\ 60° < \beta \leq 90°,$$

and the overground attenuation may be calculated by using the following equation where ℓ is in meters:

$$G(\ell) = 15.09 \left[1 - e^{-2.74 \times 10^{-3}\ell}\right], \text{dB}, 0 \leq \ell \leq 914\text{m (3,000 ft)},$$

and (2b)

$$G(\ell) = 13.86 \text{ dB}, \ell > 914\text{m (3,000 ft)}.$$

DISTANCE EFFECT ON SIGNAL DURATION

Sound exposure level (SEL) can be thought of as the sum of the maximum A-weighted sound level (ALM) and a duration component ($10 \log_{10} T$). Historically, the first order analytical approach (Ref. 3) characterized the duration (T) of an airplane flyover as directly proportional to the distance from the observer to the noise source at the point of closest approach or minimum slant distance. The duration (T) of such an event was assumed to increase linearly with distance. Thus, a doubling of the distance from the noise source increased the duration by a factor of two. In turn, the doubling of duration (T) increased the duration component of SEL by 3 dB. Similarly, the duration component increased by 10 dB when distance from the source increased by a factor of 10 or a decade.

However, analyses of field measurements have indicated that the relationship of duration to distance is not strictly linear. This original assumption of 10 dB per decade of distance overestimated the duration component. A better fit to experimental data was found by assuming that duration (T) is proportional to the 0.6 power of the distance. Thus, if the distance from the noise source doubled, the duration only increases by a factor of 1.5. Then in effect the duration component increases by 1.8 dB. It follows for every decade of distance increase, the duration component increases by 6 dB. Consistent with the current military aircraft noise data file employed in NOISEMAP, all the SEL data in this study are based on the fact that the duration component increases by 6 dB for every decade of distance increase (Ref. 4).

RESULTS

COMPARISON OF RESULTS WITH MILITARY AIRCRAFT

The performance parameters of two military aircraft, the F-4 and the B-52, were used as the input data for the NOISEMAP computer program which was run with and without the SAE recommended lateral attenuation algorithm. The resulting sound exposure level (SEL) contours were plotted in 5 dB increments ranging from 90 to 105 dB.

Tables 1 and 2 contain the information on the area (in square miles) within individual SEL contours for the F-4 and the B-52, respectively. A simple ratio analysis of the results reveals that the area of both the landing and takeoff contours produced by the NOISEMAP program using the SAE lateral attenuation model are, on the average, 16 percent smaller for the B-52, and 26 percent smaller for the F-4 than the existing NOISEMAP method.

The results in Tables 1 and 2 are graphically depicted in Figures 1 and 2. As seen in these figures, especially in Figure 1 with the F-4, there is a tendency for the difference between the two lateral attenuation models to decrease as distance increases. This convergence trend is not, however, observed in Figure 2 which illustrates the results for the B-52.*

The F-4 sound exposure level contours for approach and takeoff are shown in Figures 3 and 4. A visual comparison of the contours in these figures further substantiates the previous area analysis. The approach SEL contours (Figure 3) produced by the SAE modified version of NOISEMAP are on the average 15 percent smaller in total area than the current NOISEMAP version. A more noticeable effect is observed in the takeoff contours (Figure 4) where the SAE modified contours are on the average 31 percent smaller in total area.*

COMPARISON OF RESULTS WITH CIVIL AIRCRAFT AND AIRPORT NOISE MEASUREMENTS

John Wayne Airport in Orange County, California, has a monitoring system that maintains a record of SEL values by aircraft types and at the same time calculates the composite noise equivalent levels (CNEL) for the site. The measured data from the noise monitoring system were compared to results produced by the NOISEMAP program with the two lateral attenuation models. The CNEL contours were computed for the total airport operations and the SEL contours were computed for the composite flight operations of a B-737.

Figure 5 shows the location of the noise monitoring stations. It may be noted that the noise monitoring sites at John Wayne Airport are situated relatively close to the flight tracks. As a result of this, the angle of the airplane elevation (β) often ranges from approximately 25 degrees to 90 degrees.

At noise monitoring stations 2 and 3 the angle of the airplane elevation is in the area of 25 degrees to 60 degrees. An analysis of the data in Table 3 reveals that for these two monitoring stations, the SAE lateral attenuation model predicted levels on

*These differences are due to the NOISEMAP model being distance and spectra dependent, while the SAE model is not.

TABLE 1

AREA (SQ. MILES) WITHIN INDIVIDUAL
SOUND EXPOSURE LEVEL CONTOURS FOR A F-4

		SEL CONTOURS (dB(A))			
		90	95	100	105
NOISEMAP Lateral Attenuation Model	Takeoff	29.060	16.998	9.671	5.596
	Landing	24.248	10.024	3.778	1.569
	Total	50.467	25.606	12.703	6.600
SAE Lateral Attenuation Model	Takeoff	21.331	11.746	6.332	3.759
	Landing	19.418	8.408	3.195	1.444
	Total	39.275	19.504	9.020	4.802

TABLE 2

AREA (SQ. MILES) WITHIN INDIVIDUAL SOUND EXPOSURE LEVEL CONTOURS FOR A B-52

		SEL CONTOURS (dB(A))			
		90	95	100	105
NOISEMAP Lateral Attenuation Model	Takeoff	46.095	19.437	9.298	4.945
	Landing	15.218	8.666	4.544	2.257
	Total	59.783	27.233	13.430	6.820
SAE Lateral Attenuation Model	Takeoff	36.549	15.333	7.566	4.094
	Landing	13.152	7.691	3.845	2.143
	Total	48.812	22.727	10.991	5.940

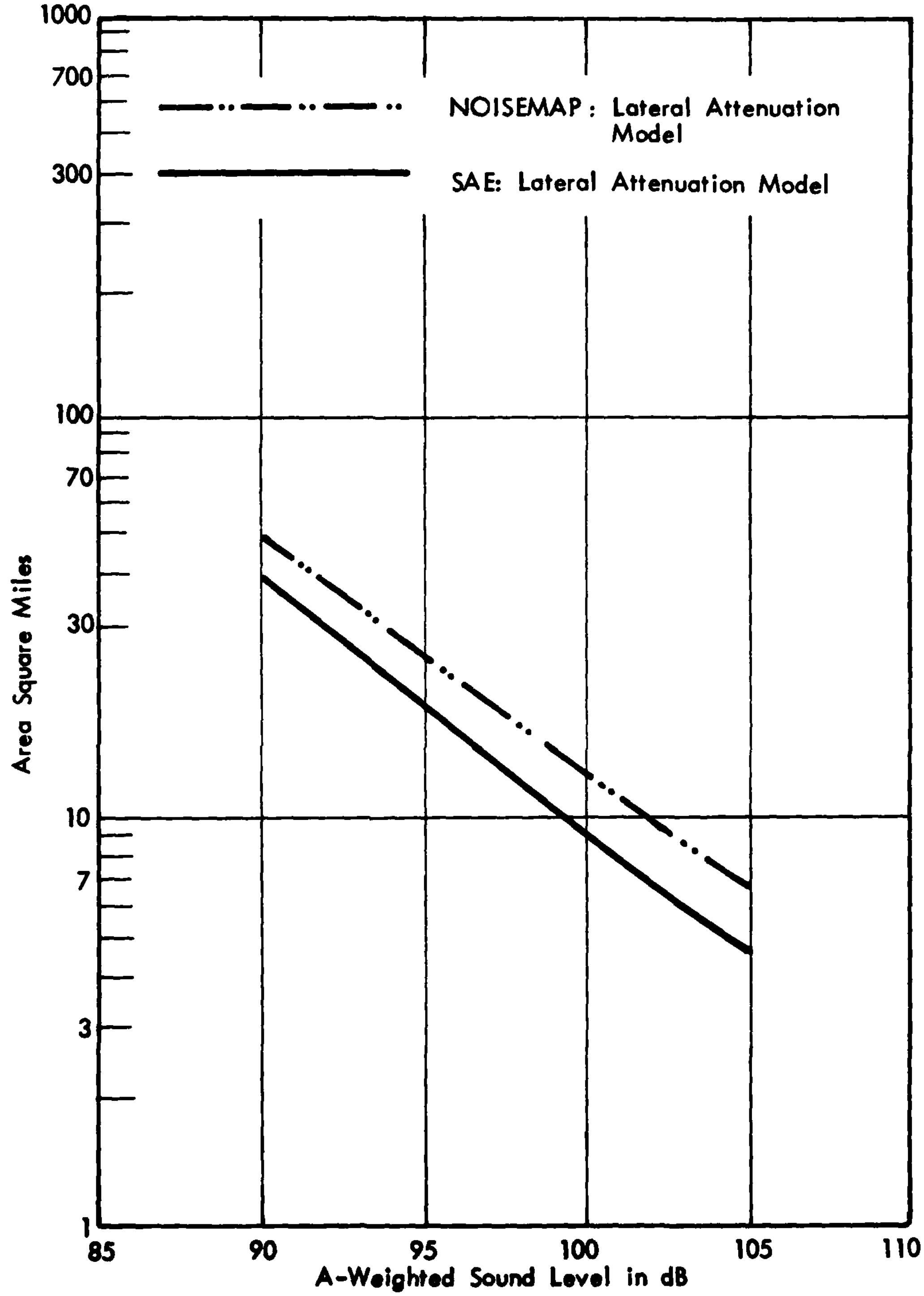


FIGURE 1. AREA WITHIN INDIVIDUAL SOUND EXPOSURE LEVEL CONTOURS RESULTING FROM A SINGLE F-4 TAKEOFF AND LANDING

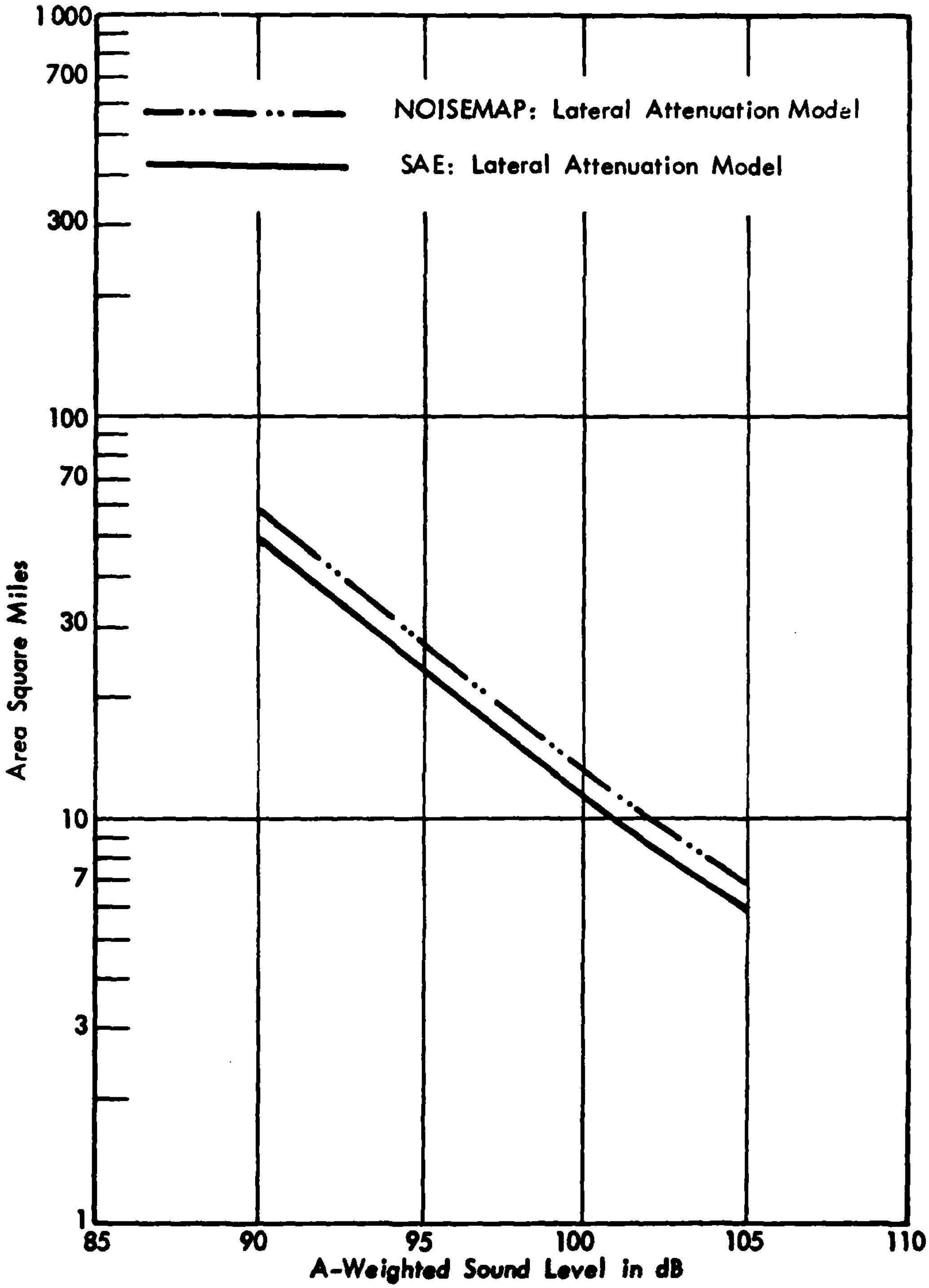
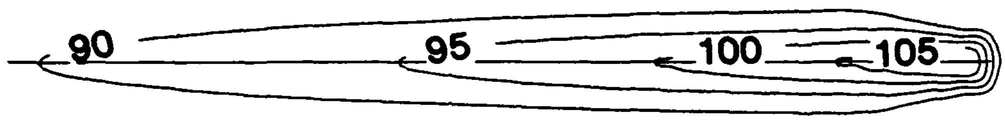
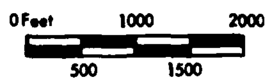
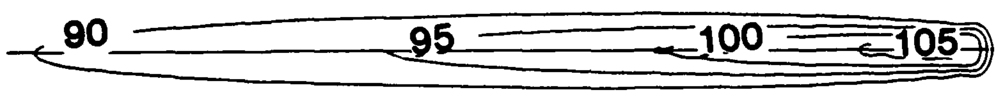


FIGURE 2. AREA WITHIN INDIVIDUAL SOUND EXPOSURE LEVEL CONTOURS RESULTING FROM A SINGLE B-52 TAKEOFF AND LANDING



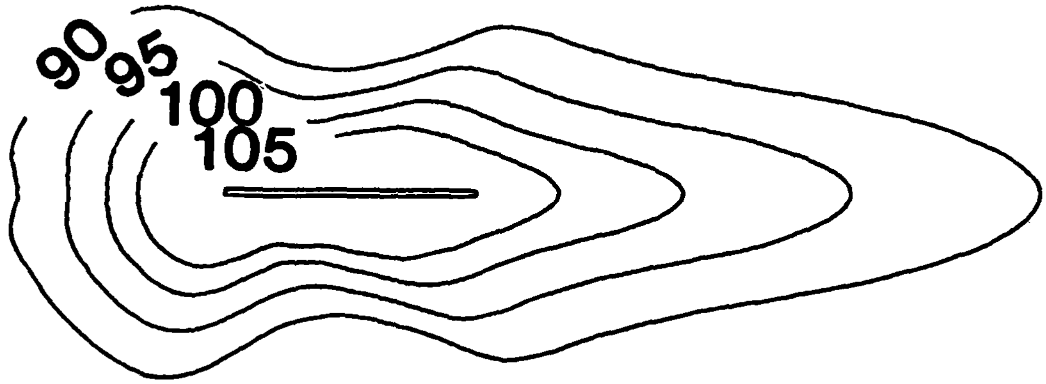
NOISEMAP: Lateral Attenuation Model



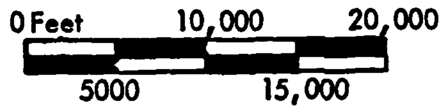


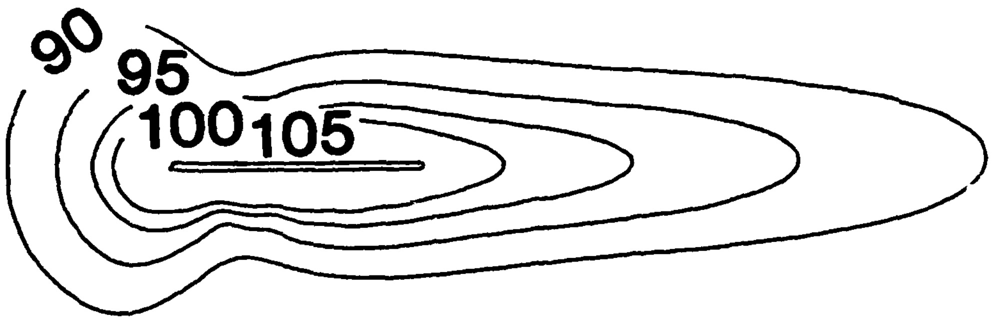
SAE: Lateral Attenuation Model

FIGURE 3. SOUND EXPOSURE LEVEL CONTOURS FROM A SINGLE F-4 LANDING



NOISEMAP: Lateral Attenuation Model





SAE: Lateral Attenuation Model

FIGURE 4. SOUND EXPOSURE LEVEL CONTOURS FROM A SINGLE F-4 TAKEOFF

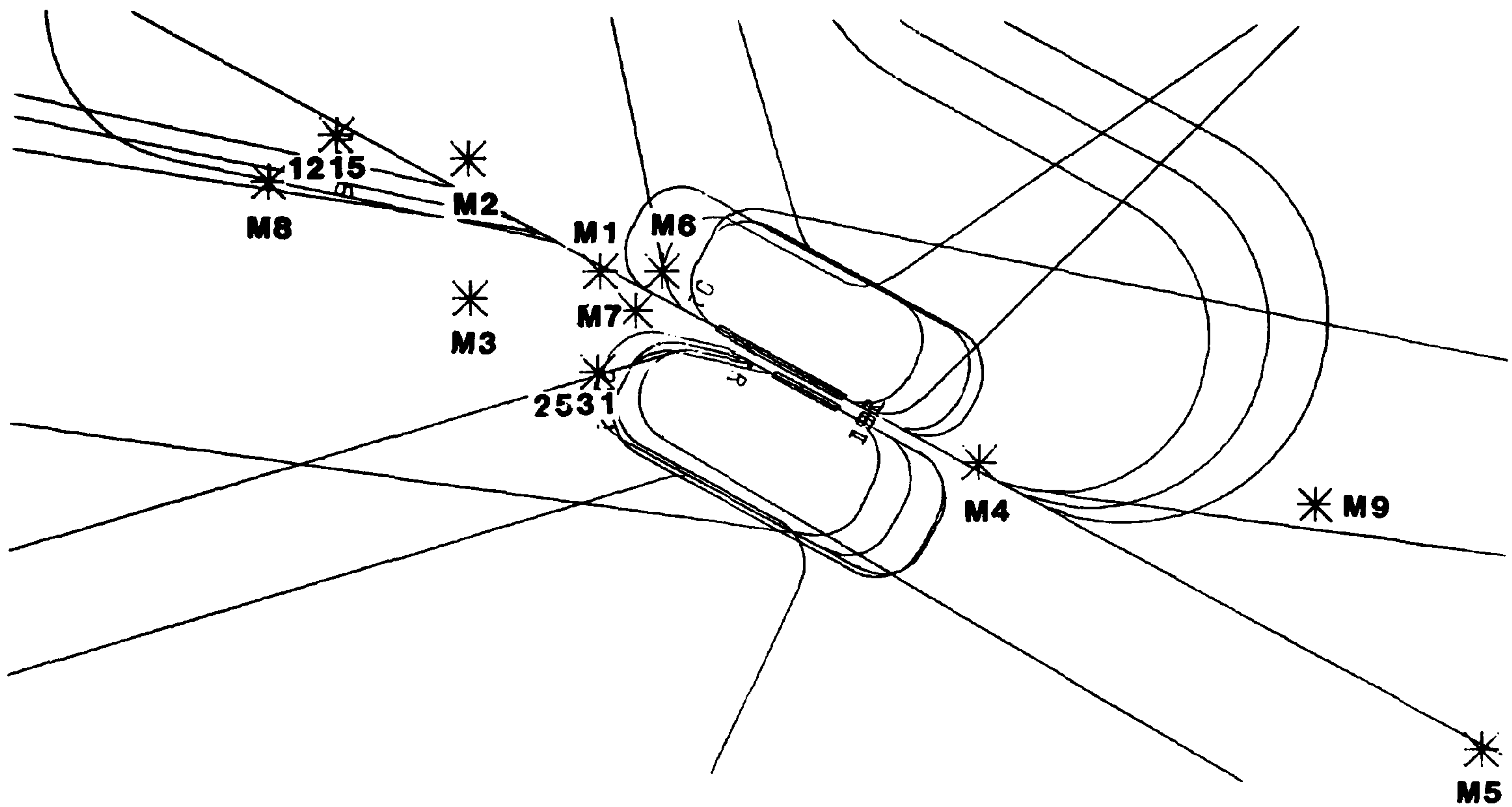


FIGURE 5. LOCATION OF MONITORING STATIONS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

TABLE 3 COMPARISON OF MEASURED CNEL NOISE VALUES WITH PREDICTED VALUES FOR THE TWO LATERAL ATTENUATION MODELS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

Monitoring Station	Measured Value	NOISEMAP Model	NOISEMAP Model - Measured	SAE Model	SAE Model-Measured
M-1	71.0	71.2	+0.2	71.2	+0.2
M-2	62.0	61.9	-0.1	61.4	-0.6
M-3	59.3	58.0	-1.3	55.3	-4.0
M-4	71.6	72.5	+0.9	71.4	-0.2
M-6	72.0	73.0	+1.0	72.9	+ .9
M-7	71.8	73.2	+1.4	71.8	0.0
M-8	60.5	60.5	0.0	60.5	0.0

the order of 0.5 to 2.7 decibels lower than the existing NOISEMAP model. In fact, over all stations, the SAE model averaged almost 1.0 decibels lower than the current NOISEMAP version. When compared to the field data, the existing NOISEMAP model prediction of CNEL was 0.3 decibels higher and the SAE model predicted CNEL was 0.5 decibels lower.

The CNEL contours produced by the two prediction models based upon airport operations are plotted in Figure 6. The single 65 CNEL contours from each of these contour sets were overlaid upon one another (in Figure 7) to allow a visual comparison. As is illustrated in Figure 7, the 65 CNEL contour from the modified NOISEMAP (SAE) version is the smaller of the two--approximately 28 percent smaller. It can also be seen, that while there is a decrease in area for the SAE NOISEMAP model, the shape of both contours is similar.

The relation of noise level to area within the individual CNEL contours was plotted in Figure 8 and tabulated in Table 4. On the average, the contours generated by the modified NOISEMAP (SAE) model are 25 percent smaller than those produced by the NOISEMAP program currently in use.

The ability of the modified version of NOISEMAP to predict sound exposure levels for individual airplane operations was also examined. A comparison of the measured SEL values with the predicted NOISEMAP values was analyzed in Table 5. The existing NOISEMAP model predicted an average of 0.3 decibels higher than the measured data (the same as the CNEL results) and the SAE-NOISEMAP version was 0.7 decibels lower. When the results of the two lateral attenuation model over all monitoring stations were compared against each other, the analysis ranged from no difference at monitoring station 1, to 5.0 decibels difference at the temporary sideline station 2531. Again, as in the CNEL comparison (Table 3), the SAE model averaged approximately 1.0 decibels lower than the currently used NOISEMAP program.

A comparison of SEL noise values from B-737 operations with contour area is illustrated in Figure 9 and the data are listed in Table 6. The results of the comparison are similar to the outcome for the CNEL analysis. The area of the SEL contours produced by the modified NOISEMAP is, on the average, 23 percent smaller than those predicted by the existing NOISEMAP program.

The shape of the SEL contours can be observed in Figure 10. The major difference is the reduction in the emphasis of the sideline effect as indicated by the SAE lateral attenuation model.

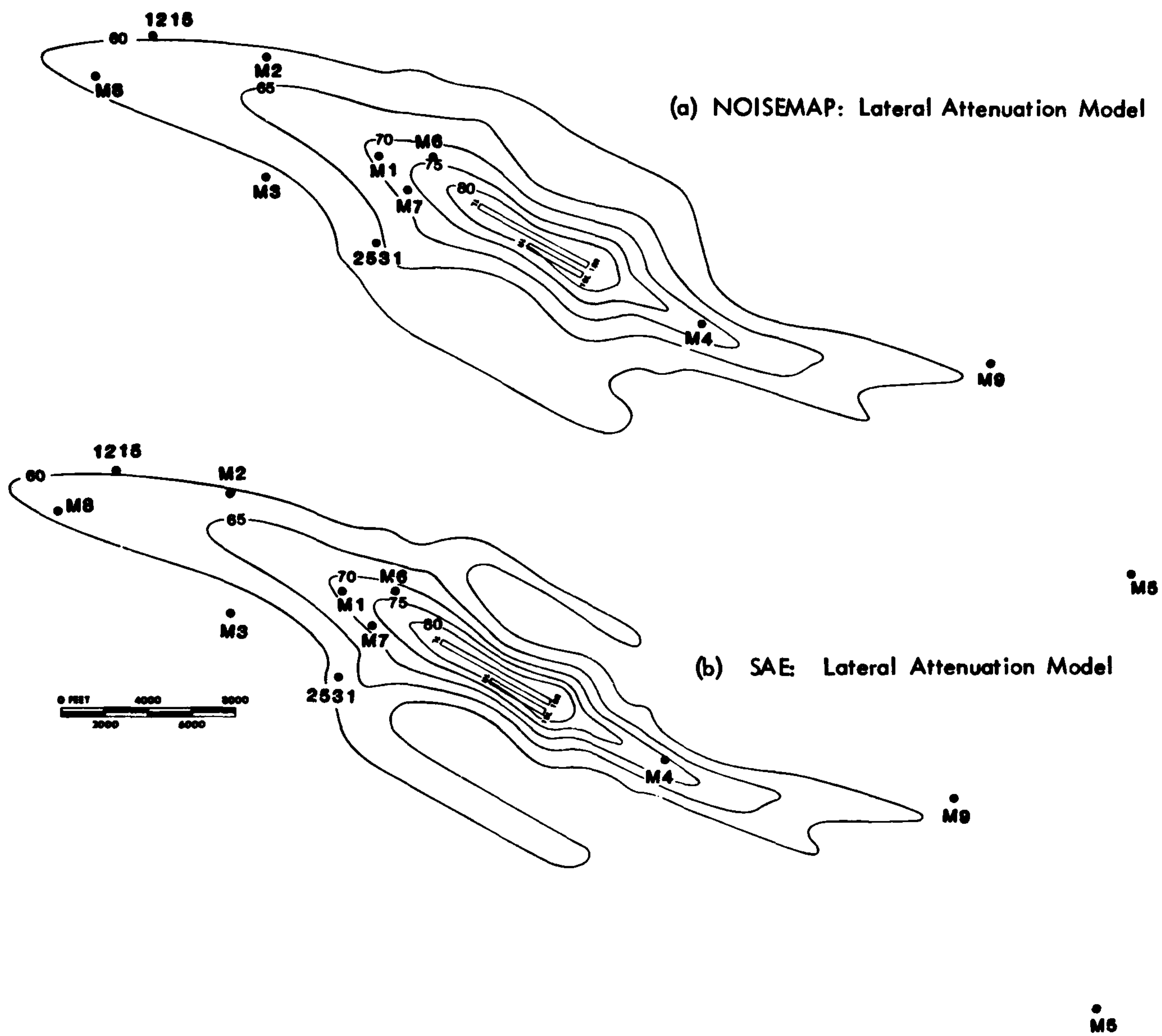


FIGURE 6. COMMUNITY NOISE EQUIVALENT LEVEL CONTOURS AND NOISE MONITORING STATIONS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

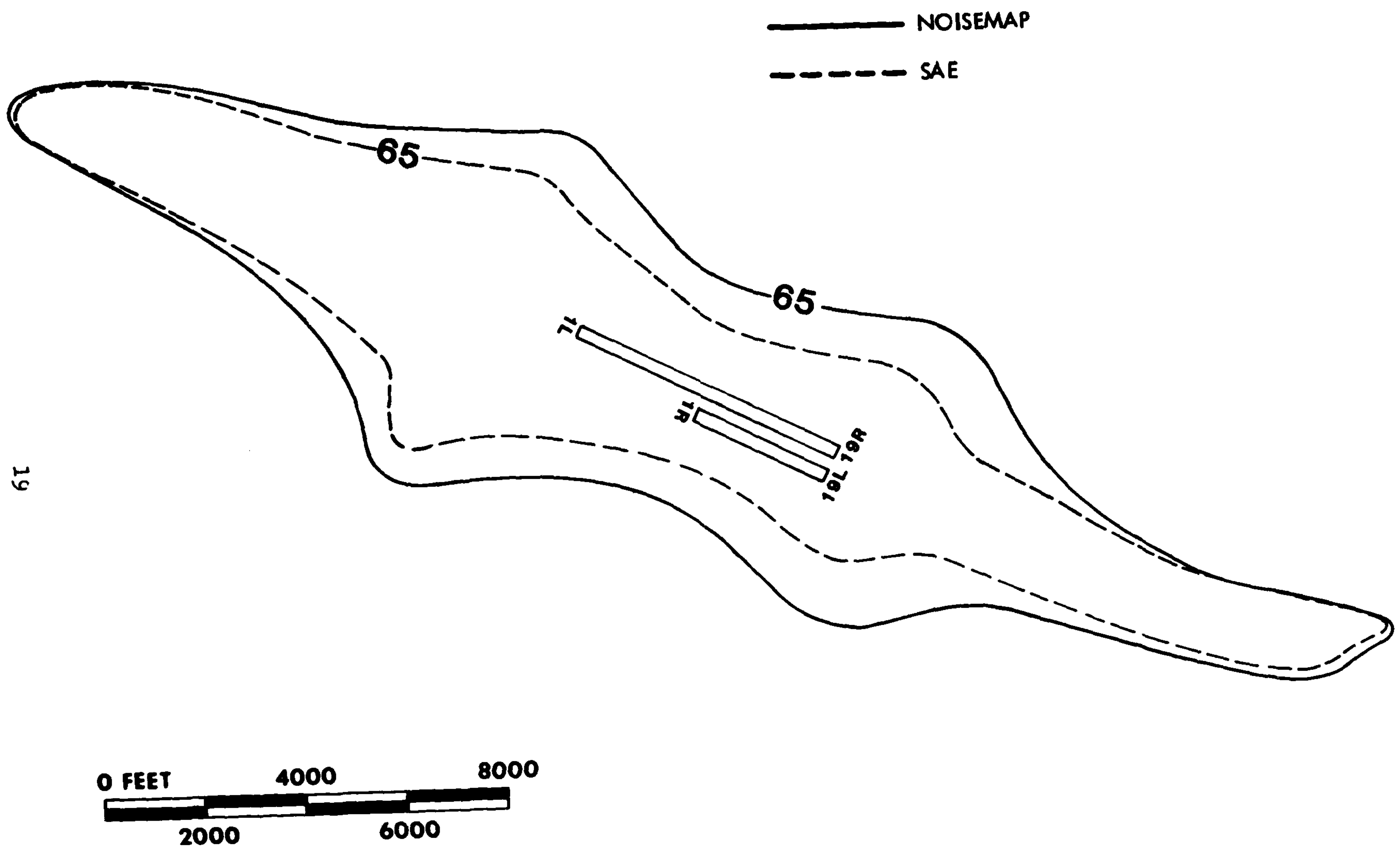


FIGURE 7. COMPARISON OF 65 CNEL CONTOURS FOR THE TWO LATERAL ATTENUATION MODELS AT JOHN WAYNE AIRPORT

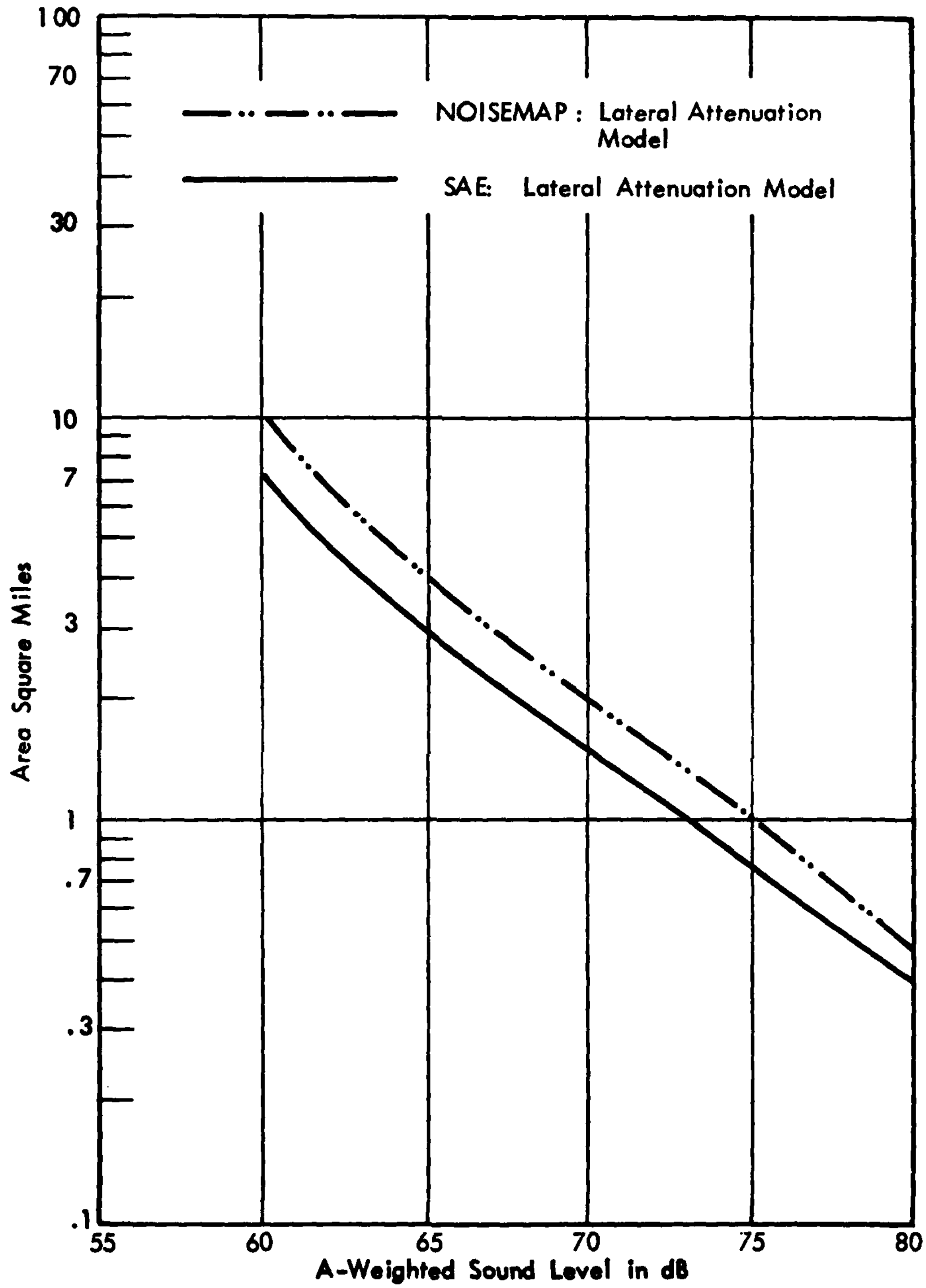


FIGURE 8. AREA WITHIN INDIVIDUAL COMMUNITY NOISE EQUIVALENT LEVEL CONTOURS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

TABLE 4 AREA (Sq.Mi) WITHIN INDIVIDUAL CNEL CONTOURS RESULTING FROM OPERATIONS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

CNEL CONTOUR	NOISEMAP MODEL	SAE MODEL
60	10.102	7.263
61	8.481	5.903
62	6.914	4.773
63	5.620	3.987
64	4.785	3.424
65	4.115	2.953
66	3.523	2.544
67	3.011	2.200
68	2.621	1.902
69	2.268	1.661
70	1.971	1.457
71	1.723	1.287
72	1.514	1.141
73	1.317	1.001
74	1.148	0.887
75	0.997	0.759
76	0.861	0.655
77	0.735	0.574
78	0.638	0.500
79	0.536	0.441
80	0.459	0.389

TABLE 5. COMPARISON OF MEASURED MEAN-SQUARE AVERAGE SEL NOISE VALUES WITH PREDICTED VALUES FOR THE TWO LATERAL ATTENUATION MODELS FROM OPERATIONS OF A B-737 AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA.

Monitoring Station	Approx. Angle of Elevation	Measured Value		NOISEMAP Model	NOISEMAP Model - Measured	SAE Model	SAE Model - Measured
		Energy Average	Standard Deviation				
M-1	79°	100.7	2.0	101.6	+0.9	101.6	+0.9
M-2	55° - 29°	92.8	2.0	92.7	-0.1	91.8	-1.0
M-3	35° - 23°	89.7	2.0	88.4	-1.3	85.8	-2.6
M-4	49°	101.9	2.9	102.6	+0.7	102.3	+0.4
M-5	83° - 15°	88.7	4.5	90.4	+1.7	90.4	+1.7
M-6	40°	102.7	2.8	104.1	+1.4	103.3	+0.6
M-7	43°	103.0	3.1	103.2	+0.2	102.4	-0.6
M-8	76° - 39°	92.0	2.1	92.0	0.0	91.9	+0.1
2531	13°	92.6	-	90.6	-2.0	85.5	-7.1
1215	85° - 35°	89.8	-	90.8	+1.0	90.3	+0.5

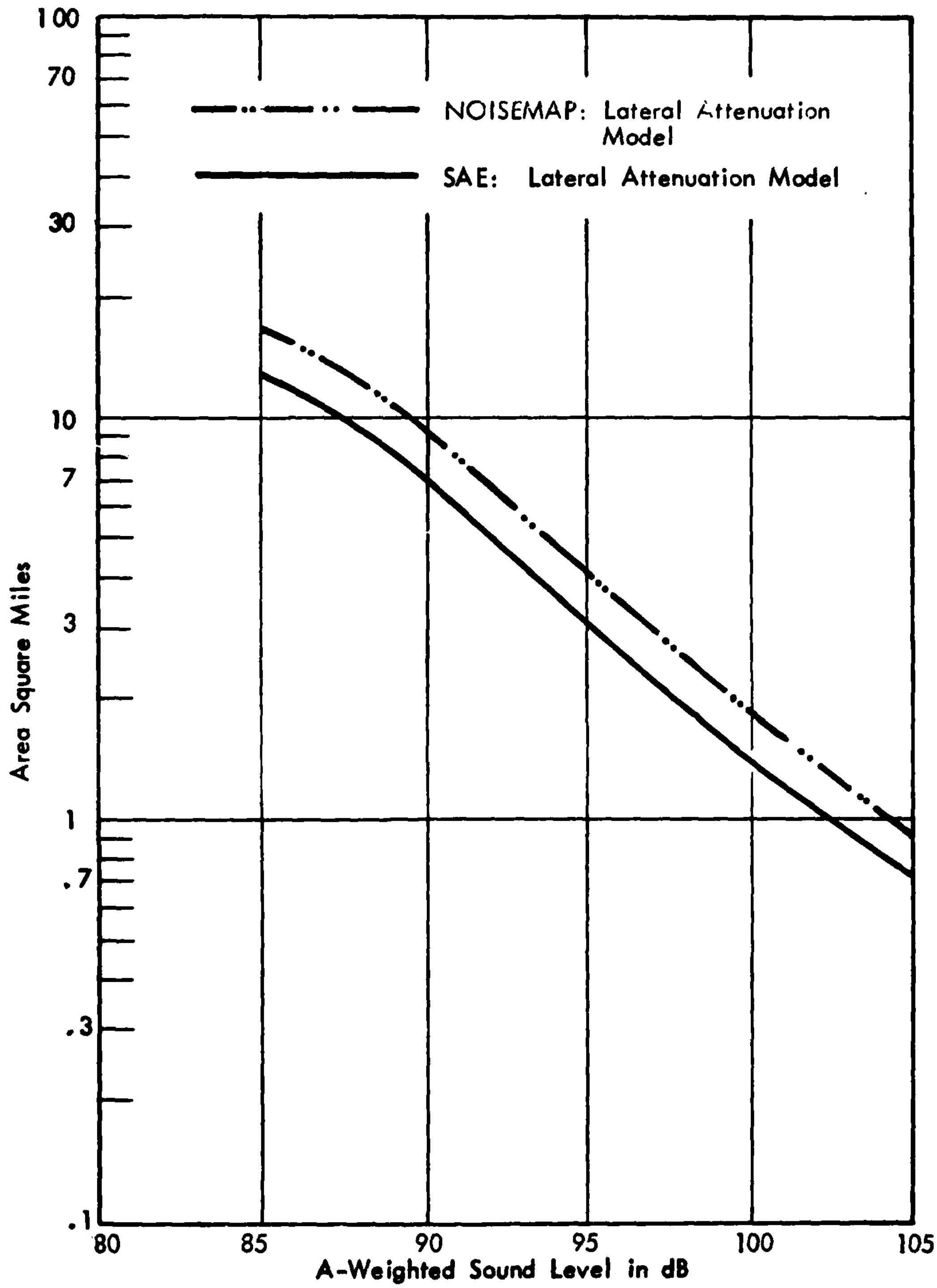
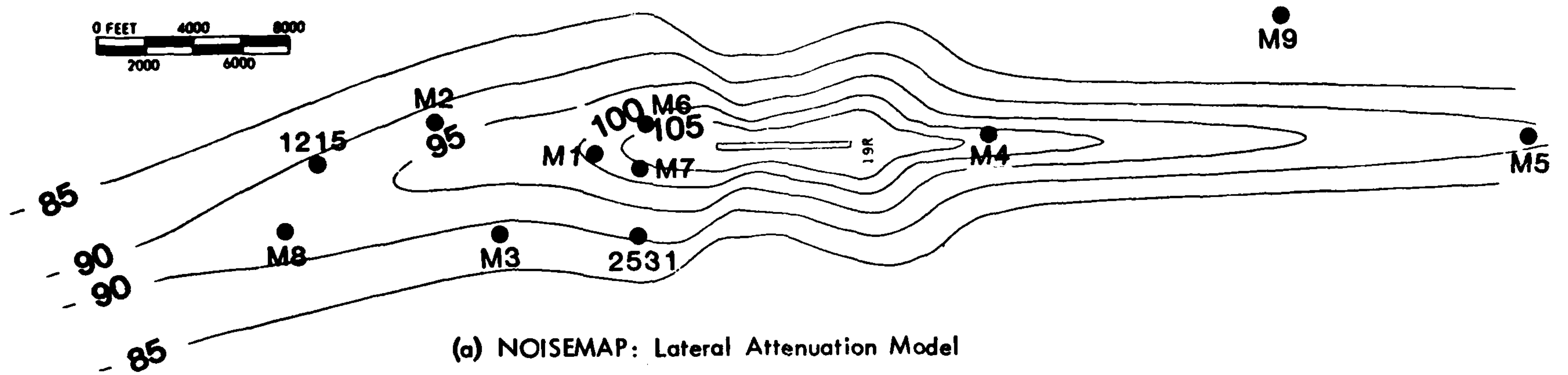


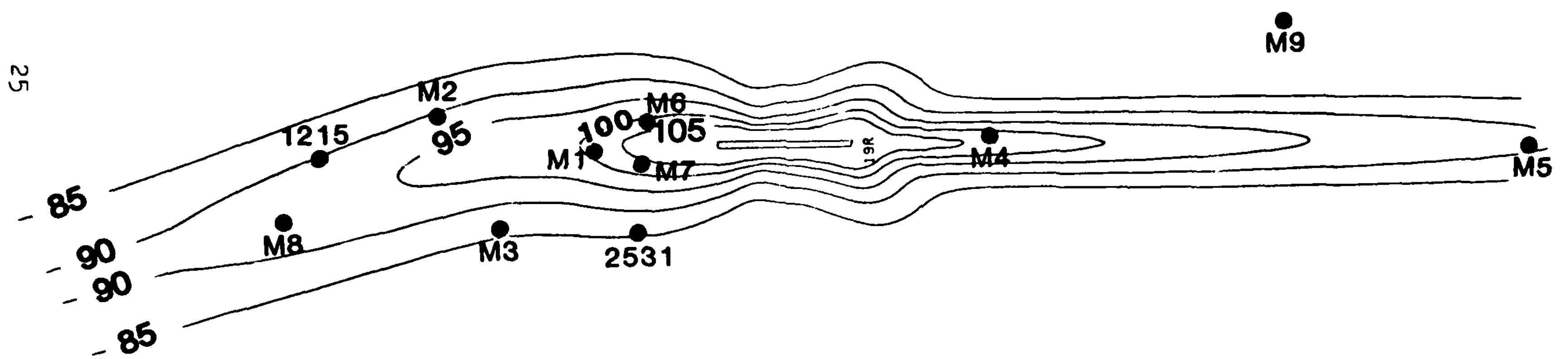
FIGURE 9. AREA WITHIN INDIVIDUAL SOUND EXPOSURE LEVE CONTOURS RESULTING FROM B-737 OPERATIONS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

TABLE 6 AREA (Sq.Mi) WITHIN INDIVIDUAL SEL CONTOURS RESULTING FROM OPERATIONS OF A B-737 AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

SEL CONTOUR	NOISEMAP MODEL	SAE MODEL
85	17.063	12.898
86	15.603	11.798
87	14.100	10.752
88	12.659	9.705
89	11.157	8.628
90	9.544	7.399
91	7.930	6.077
92	6.752	5.162
93	5.786	4.413
94	4.947	3.758
95	4.191	3.177
96	3.553	2.678
97	2.980	2.251
98	2.534	1.914
99	2.151	1.619
100	1.856	1.415
101	1.605	1.246
102	1.408	1.094
103	1.217	0.965
104	1.051	0.840
105	0.912	0.723



(a) NOISEMAP: Lateral Attenuation Model



(b) SAE: Lateral Attenuation Model

FIGURE 10. B-737 SOUND EXPOSURE LEVEL CONTOURS AND NOISE MONITORING STATIONS AT JOHN WAYNE AIRPORT, ORANGE COUNTY, CALIFORNIA

CONCLUSIONS

The differences between the current NOISEMAP computer program and the modified version containing the SAE lateral attenuation algorithm were not exhaustively evaluated due to a paucity of field measurement data predominantly at the lower angles of evaluation associated with landing or taking off procedures. It is anticipated that with additional field measurement data for elevation angles $\beta < 25$ degrees, it will be possible to conclude which of the two lateral attenuation models is the more effective at predicting accurate SEL and cumulative exposure values both near the airport and at some distance into the community.

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